Search for New Particles Decaying to Dijets

Robert M. Harris

Exotics & QCD Meetings

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Motivation & Strategy

- To search for new particles decaying to dijets, which appear as bumps in dijet mass distribution.
  - Set limits on cross section & mass of new particles if no discovery.
  - Example models are axigluons, colorons, q*, ρ_T, W' ,Z' , E_6 Diquarks.

- Complete a physics result in time for Winter Conferences.
  - Show that CDF is making progress understanding jets in run 2.
  - Demonstrate run 2 is already more sensitive to new physics than run 1.

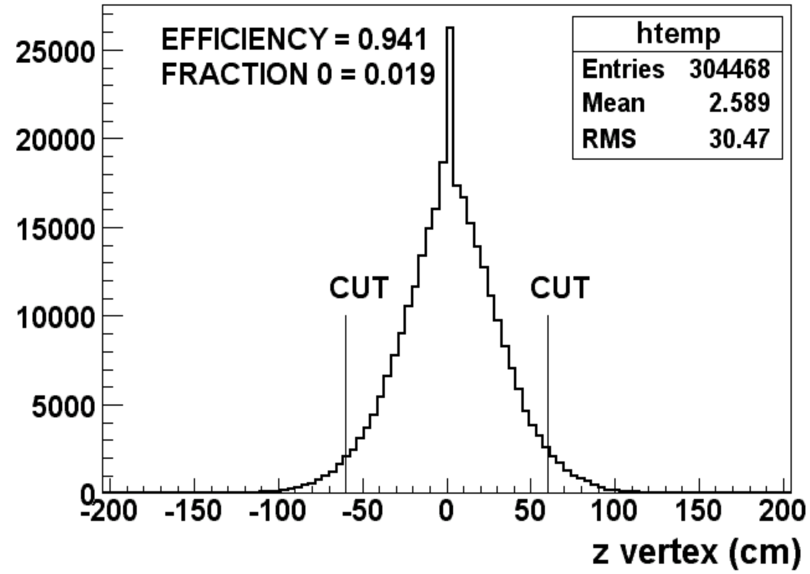
- Repeat run 1 analysis as closely as possible.
  - We've done this before and can benefit from our run 1 experience
    - References: PRD 55, R5263 (1997); PRL 74, 3538 (1995)
  - Allows comparison of run 2 with run 1 data as a check.
    - We calibrate the run 2 jet energy to the run 1 jet energy for expedience.
    - Now the official procedure of the Jet Corrections Group and Jet Subgroup.

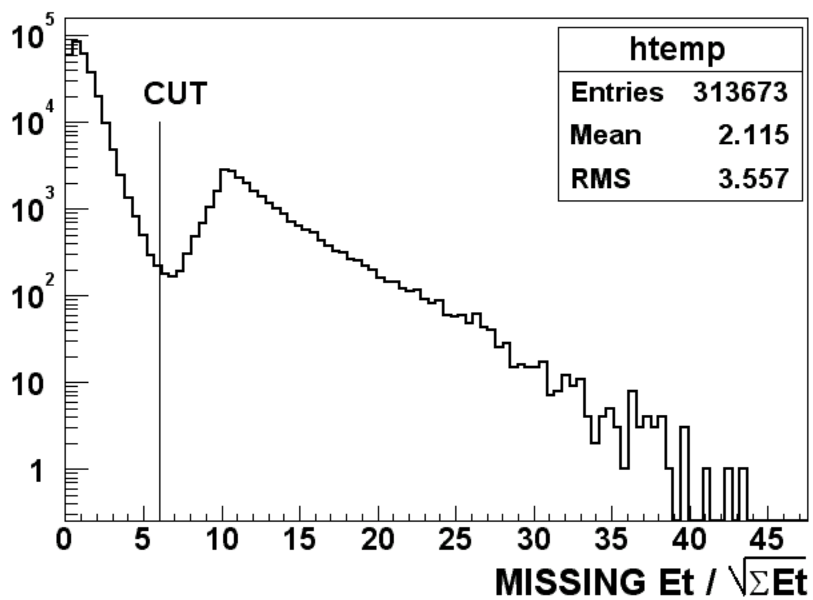
Dijet Mass Analysis

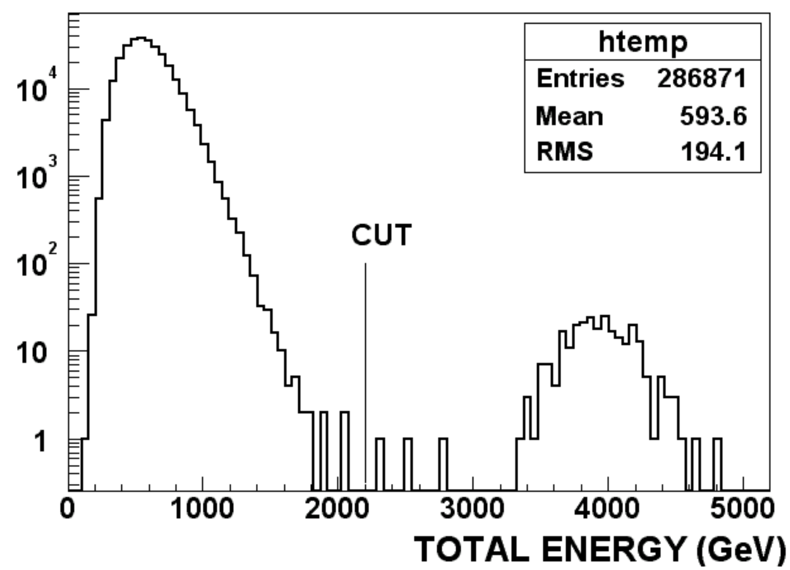
- As in run1, use J20, J50, J70 & J100 triggers.
  - 52 pb^{-1} of Frank Chlebana's ntuples from Dec 2001 – Sep 2002.
- As in run 1, we apply the following cuts.
  - | Z Vertex | < 60 cm to insure cal towers project from vertex. Efficiency ≅ 94%.
  - Missing $E_T/\mathrm{sqrt}(\Sigma E_T) < 6.0$ to eliminate cosmic rays.
  - $\Sigma E < 2.2$ TeV (2.0 TeV in run 1) to eliminate unphysical noise.
- Get the two leading jets (highest E_T), with cone R=0.7, and correct the energy.
  - Relative correction vs. detector η comes from dijet balancing in J20 (Bhatti & Flanagan).
    - Need to replace this with dijet balancing from J20, J50, J70 and J100.
  - Absolute corrections for central response, out-of-cone energy & und event from run 1.
  - Cal E-scale corrections: increase CEM scale by 0.9%, CHA scale by 4%.
  - Jet E-scale using photon-jet balancing results in run 2 and run 1 from G. Latino.
    - Increase jet energy by 4.41% +/- 0.50%. Completes "calibration" of run 2 jet energy to run 1.
    - CDF6152 & http:/cdfsga.fnal.gov/internal/people/links/GiuseppeLatino/links/talk_11_13_02.ps.gz
  - This procedure has been made "official" for winter conferences and code is available.
- As in run 1, require each leading jet have $|\eta| < 2$, $|\cos\theta^*| = |\tanh([\eta_1-\eta_2]/2)| < 2/3$.
  - Reduces QCD background (t-channel) when searching for new particles (s-channel).
- As in run 1, define dijet mass $M = \mathrm{sqrt}(E^2 - \bar{p}^2)$, where $E=E_1+E_2$, $\bar{p} = \bar{p}_1 + \bar{p}_2$.

Selection Cuts in J100 Sample

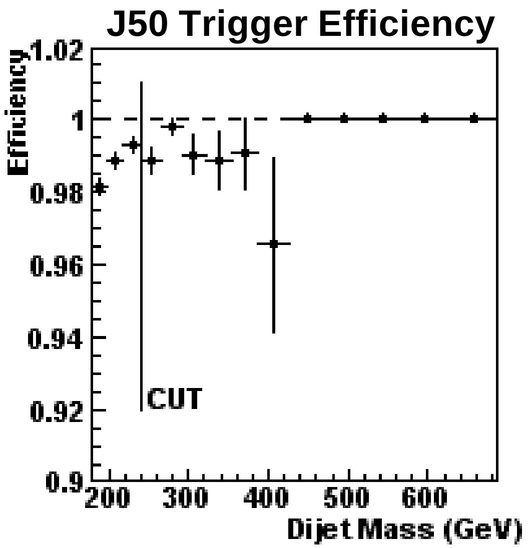
- z vertex cut is 94% efficient.
  - Vertex strategy 1 algorithm fails on 2% of events and z=0.0 is assigned.
- Missing Et significance cut is crucial for elimination of cosmics rays
  - Efficiency >> 99%
- Total energy cut for obvious junk.

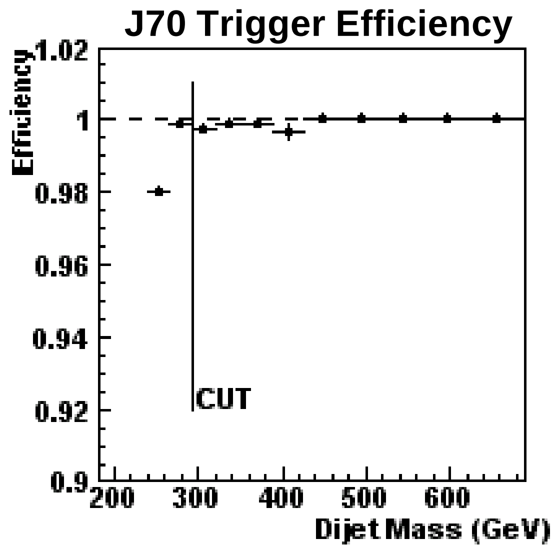


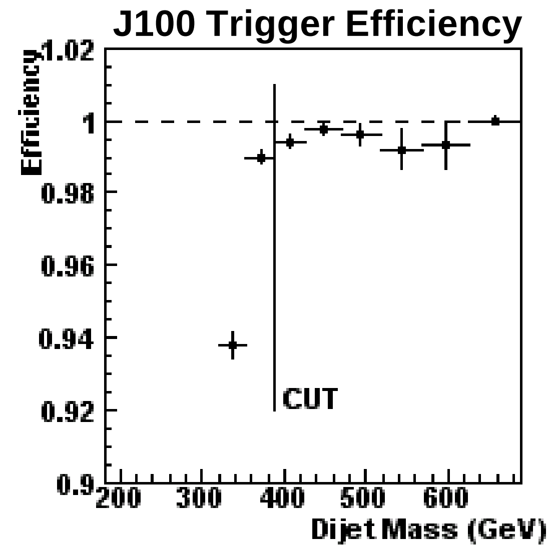




Dijet Mass Trigger Efficiency



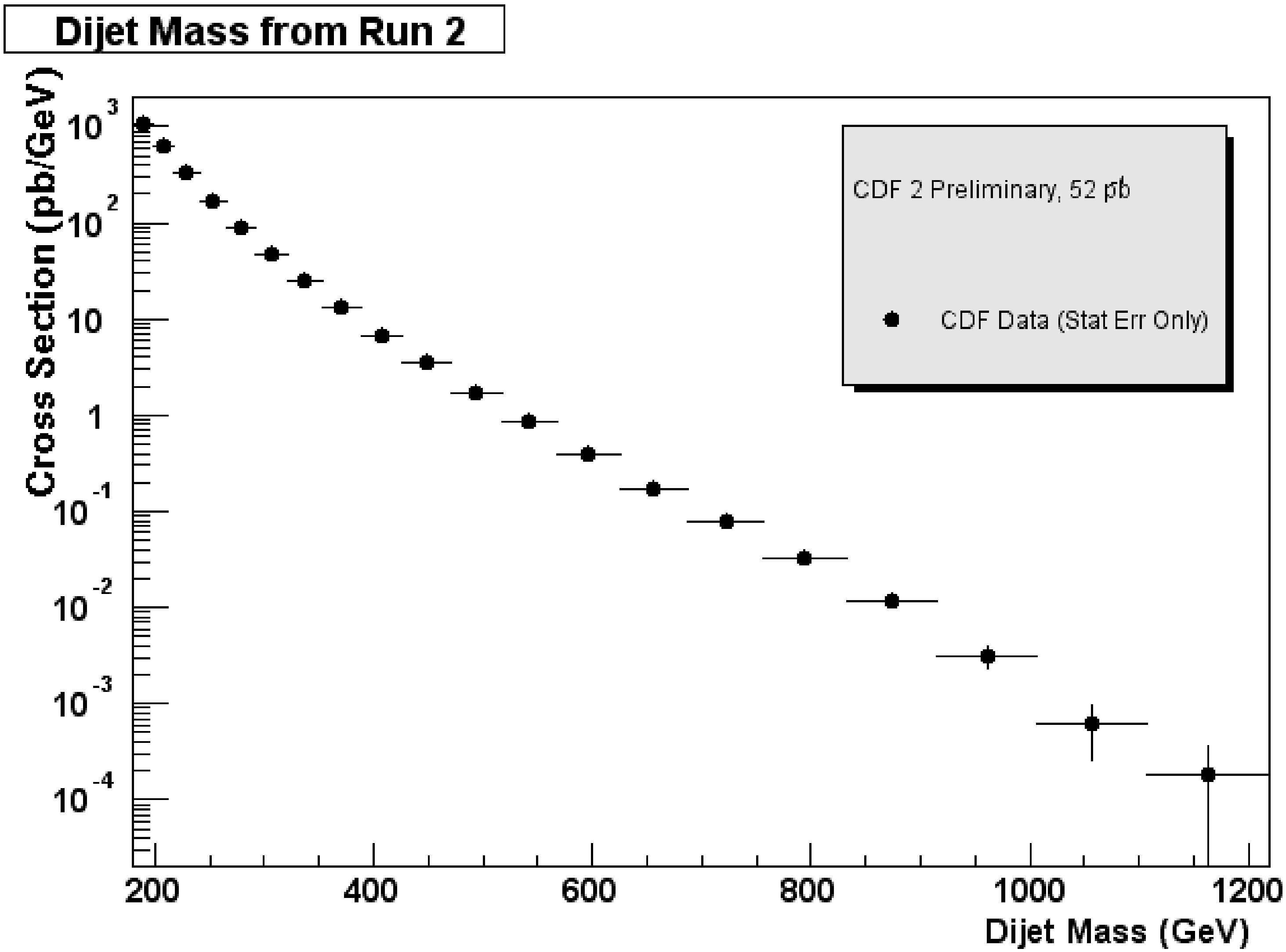




Trigger	Mass Cut (GeV)	Efficiency at Threshold			Luminosity/Prescale (pb^{-1})		
		Run 1A	Run 1B	Run 2	Run 1A	Run 1B	Run 2
Jet 20	180	1	1	1	19.1/500	87.3/1000	51.7/240
Jet 50	241	0.99	0.98	0.989	13.1/20	87.3/40	51.7/20
Jet 70	292	0.95	0.96	0.997	19.1/6	87.3/8	51.7/8
Jet 100	388	0.97	0.96	0.994	19.1/1	87.3/1	51.7/1

- Using same thresholds and mass bins as run 1, calculate cross section.
  - Apply the run 2 luminosity, prescales, trigger efficiency and z vertex efficiency.

Dijet Mass Distribution



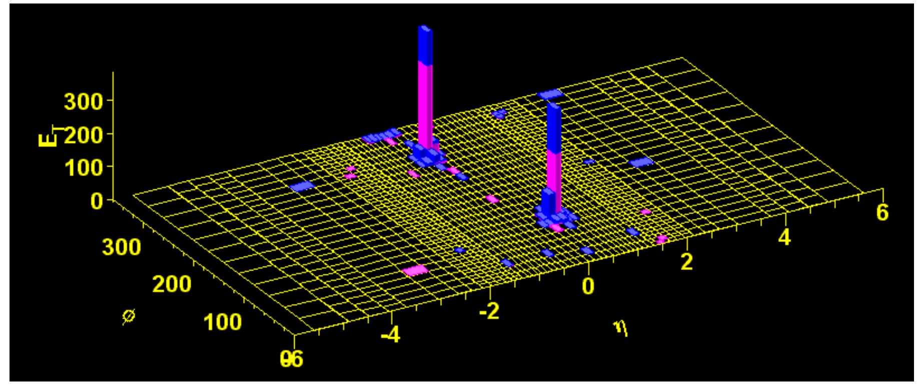
High Mass Dijet Event

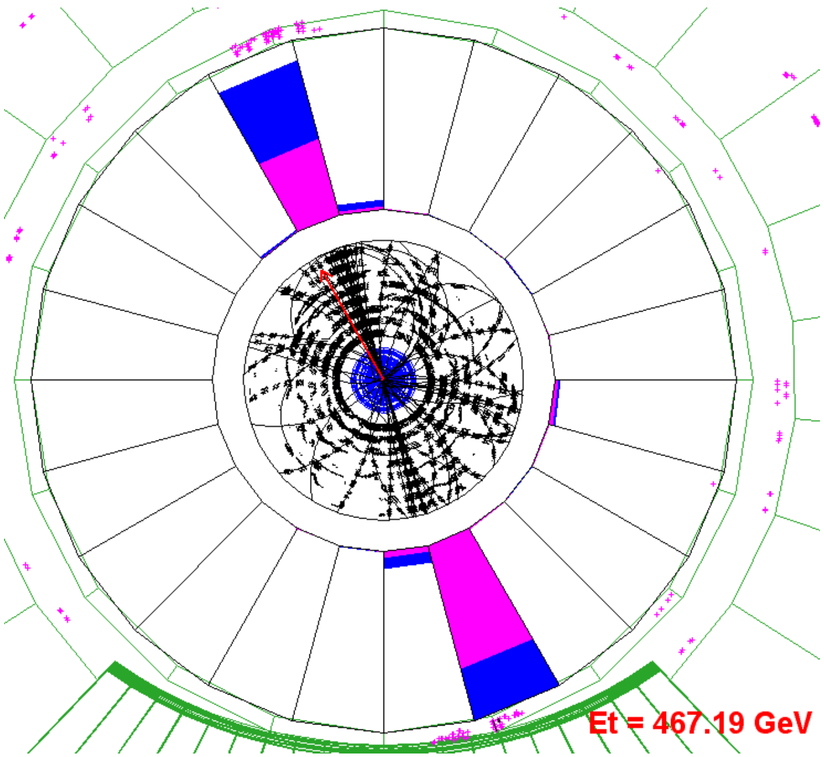
Run 151128 event 295868

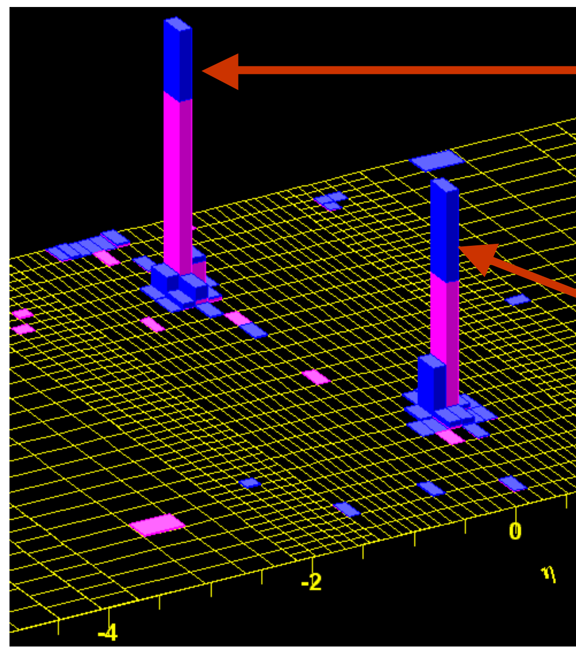
Dijet Mass = 1197 GeV (corr)

cos θ^* = 0.36

z vertex = 54 cm







J2 E_T = 471 GeV (raw)
= 556 GeV (corr)

J2 η = -0.32 (detector)
= -0.55 (correct z)

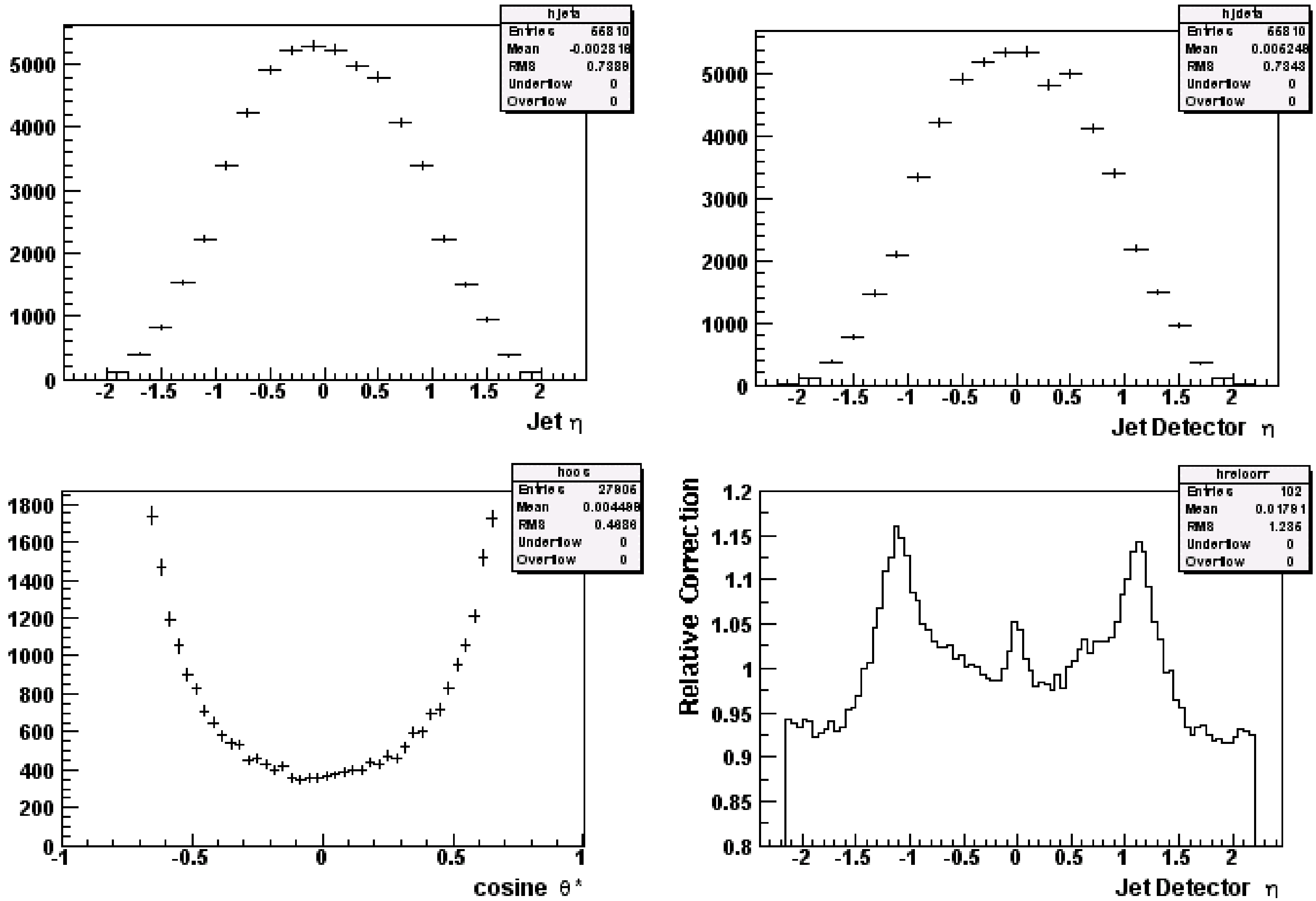
J1 E_T = 480 GeV (raw)
= 561 GeV (corr)

J1 η = 0.42 (detector)
= 0.20 (correct z)

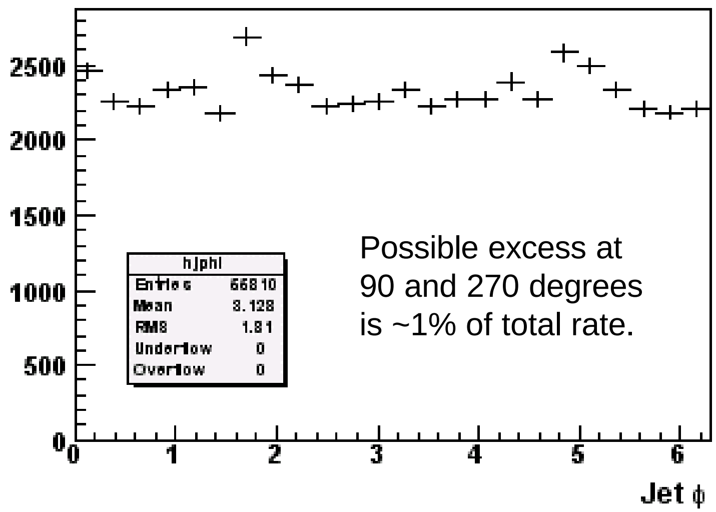
Corrected E_T and mass are preliminary

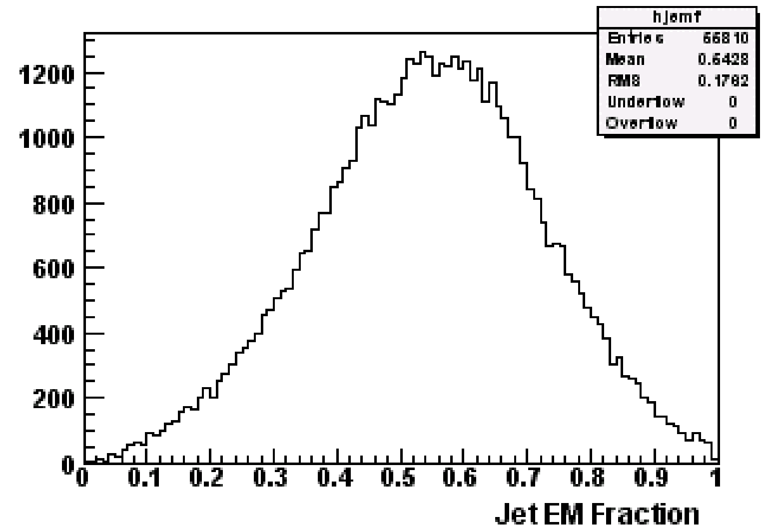
Angular Variables & Relative Corrections

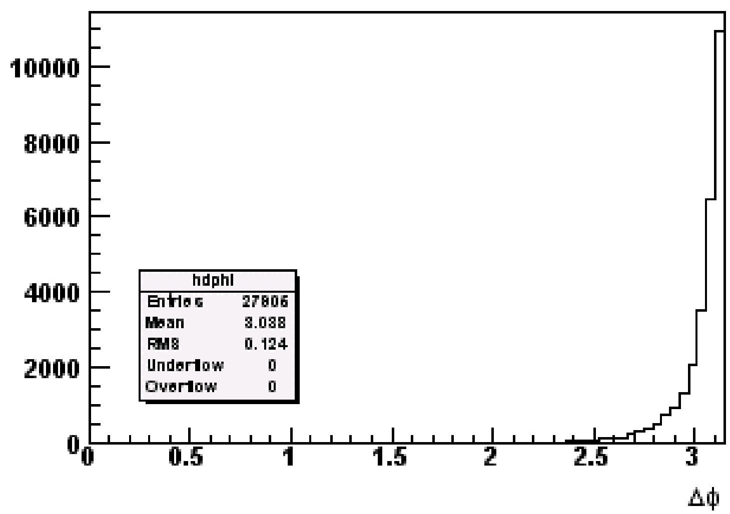
J100 with M>388 GeV

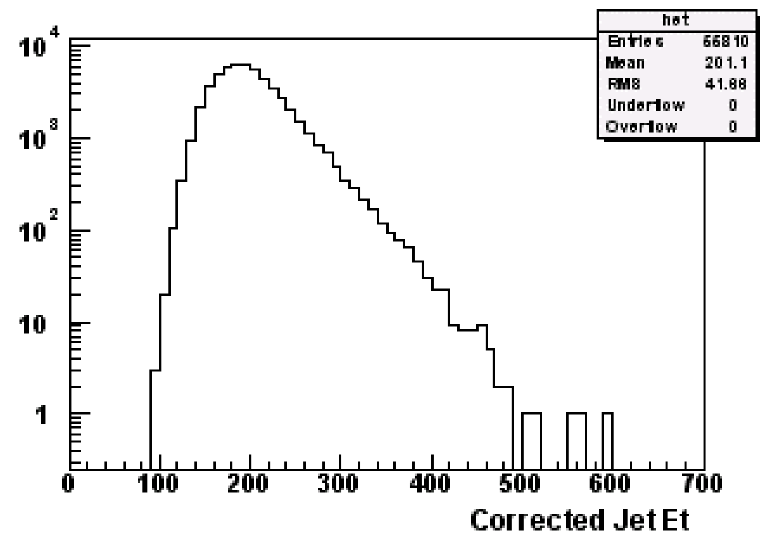


Miscellaneous Variables
J100 with M>388 GeV

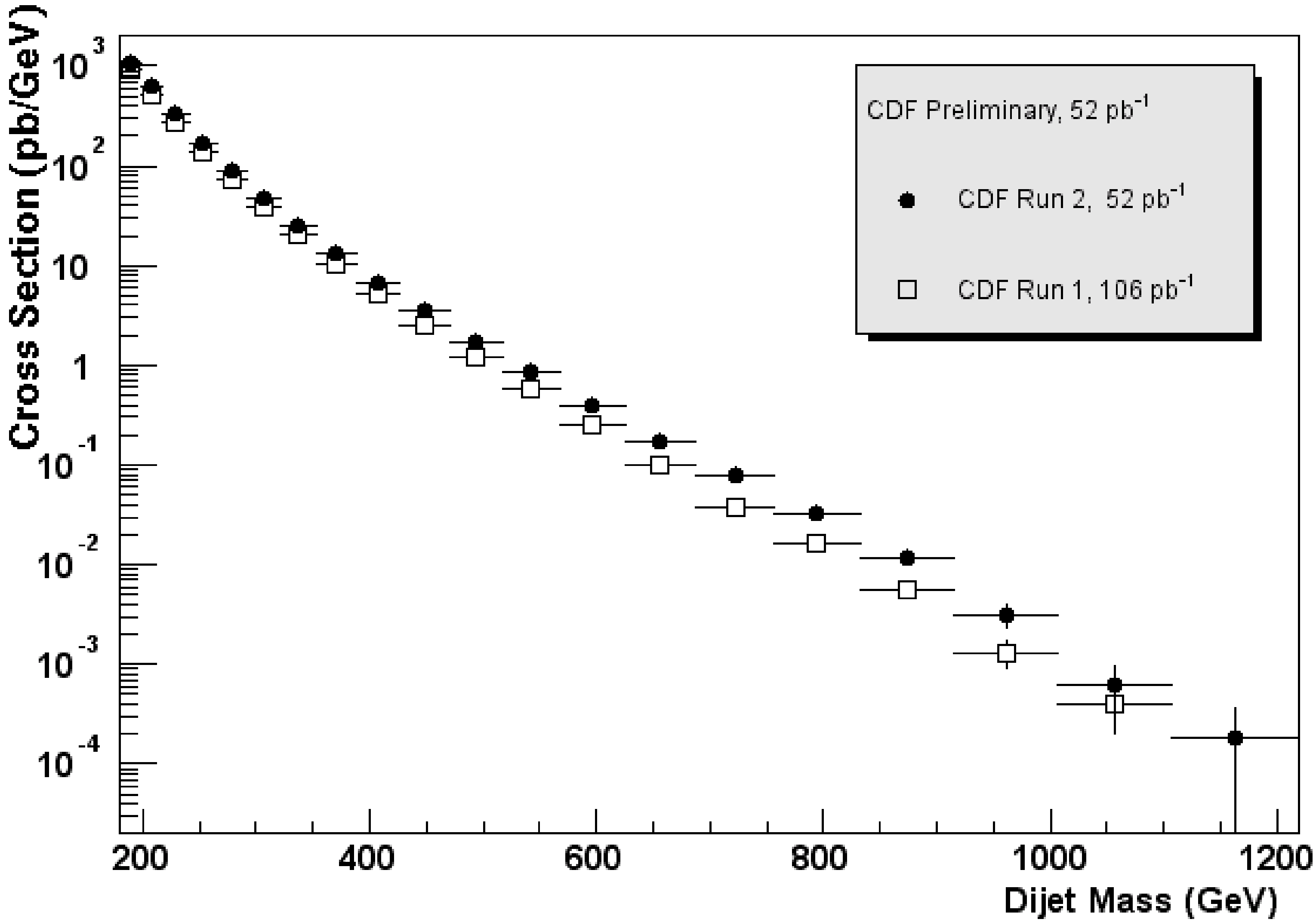




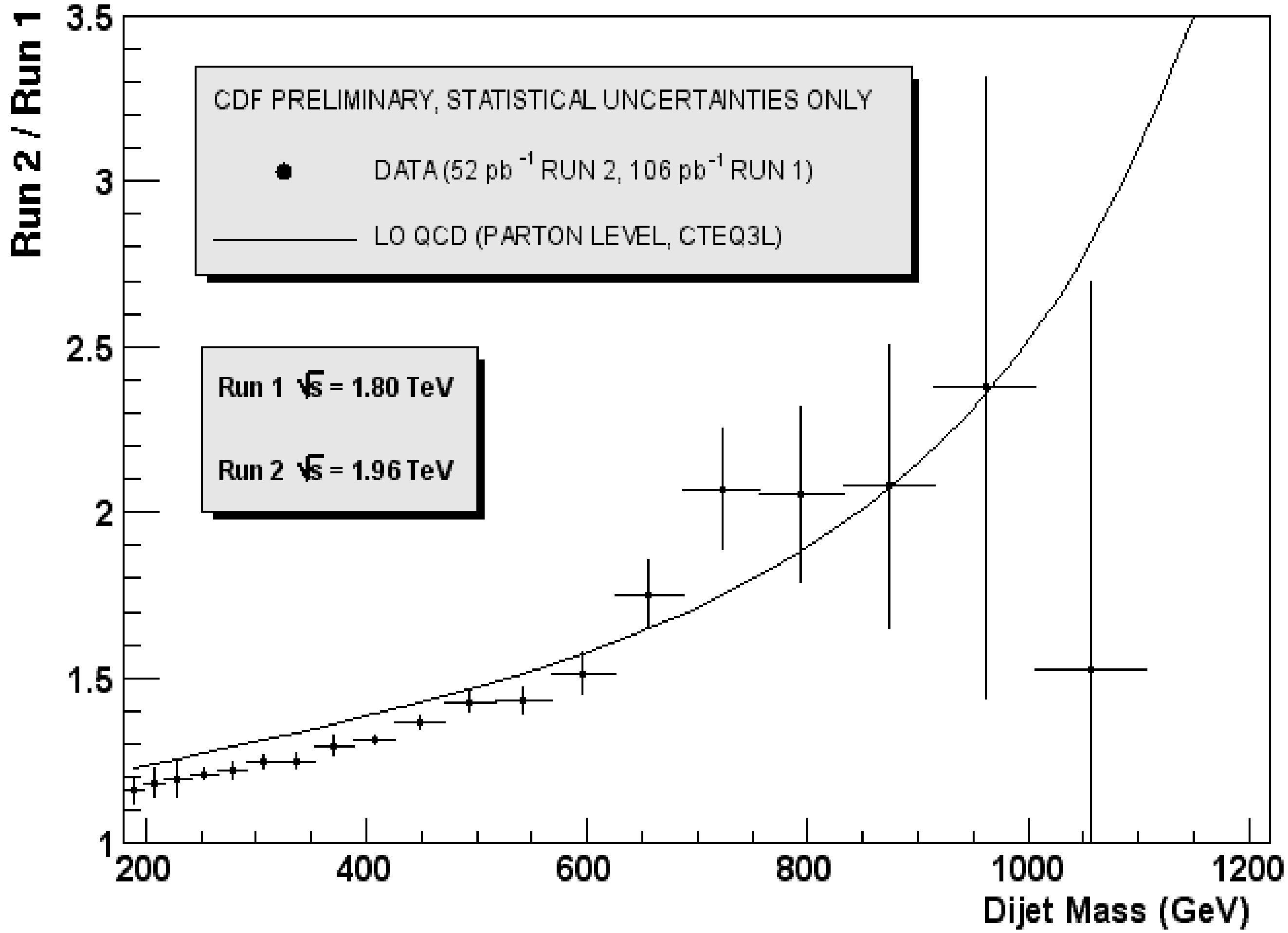




Dijet Mass from Run 2 & Run 1



Dijet Mass Ratio: Run 2 / Run 1

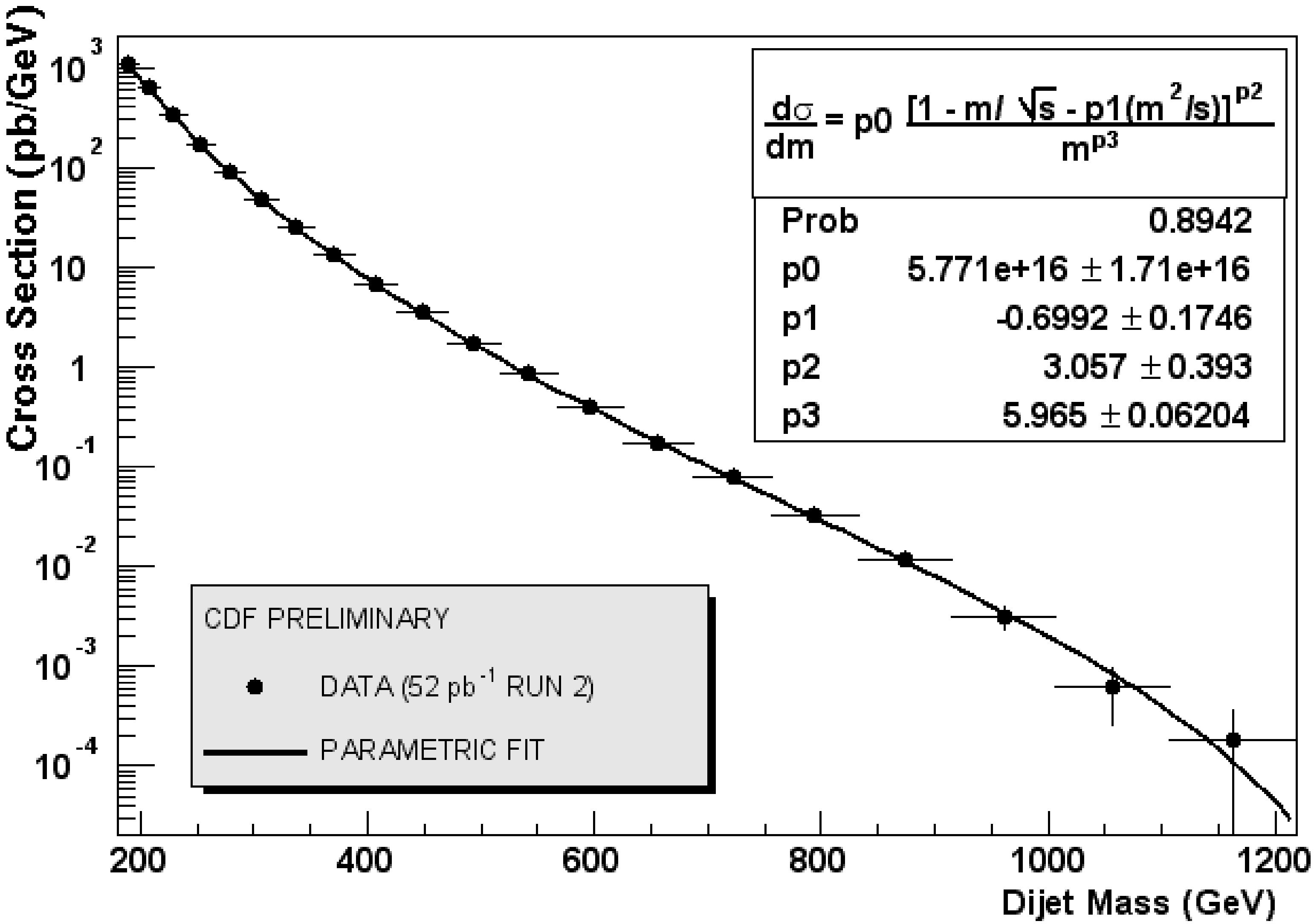


- Run 2 / Run 1 agrees with theory to ~6% in rate (~1% in energy scale).
  - Calibration of run 2 jet energy to run 1 works. The 4.4% energy increase was necessary.

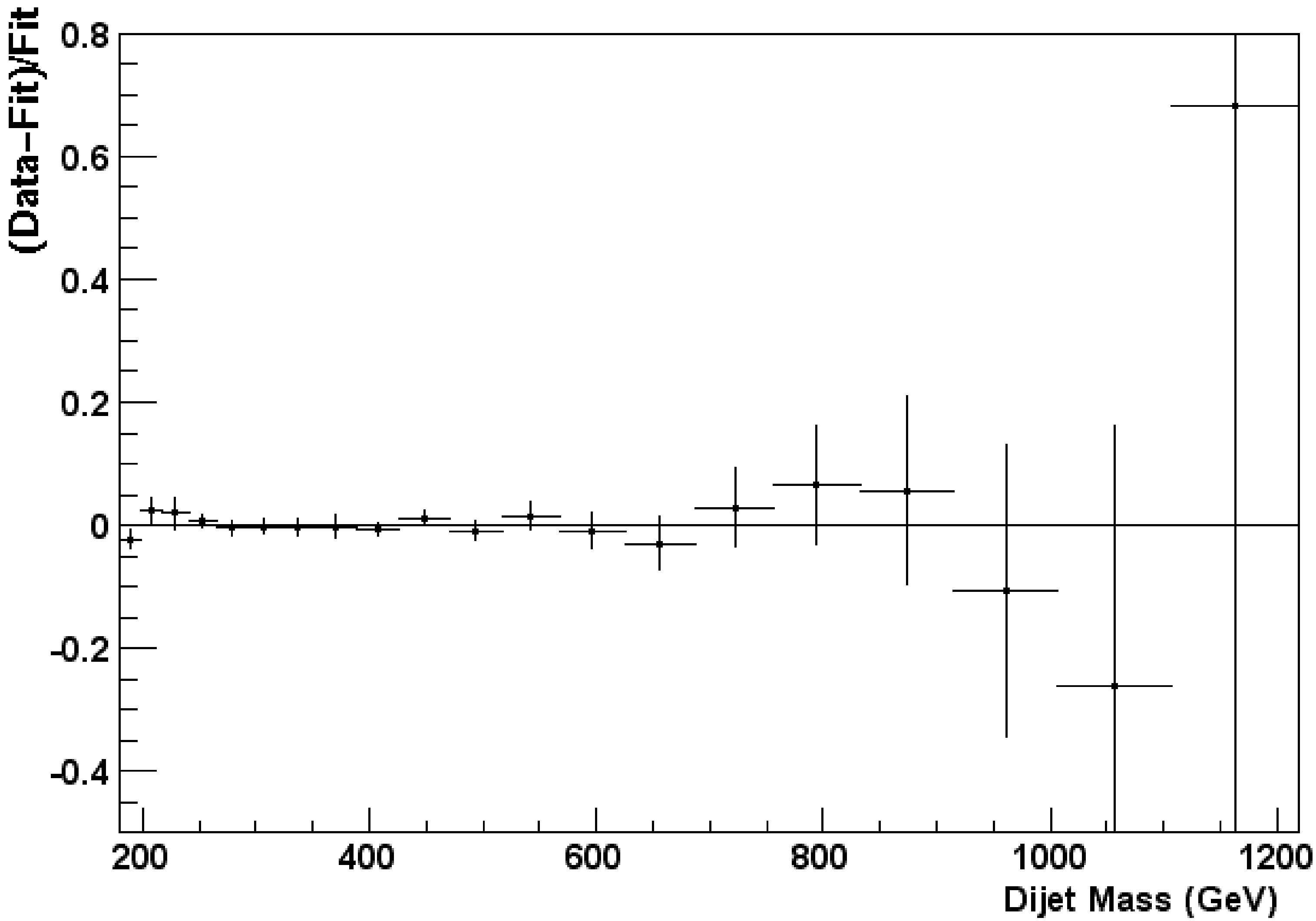
Dijet Mass Search

- Search for resonances
  - As in Run 1, we fit the dijet mass distribution with a background parameterization inspired by QCD.
    - $$\frac{d\sigma}{dm} = \frac{p_0(1 - m/\sqrt{s} - p_1 m^2/s)^{p_2}}{m^{p_3}}$$
    - Numerator models the $(1-x)^n$ behavior of parton distributions.
    - Denominator models the $1/m^p$ behavior of QCD matrix element.
  - The fit is good, almost too good!
  - No obvious evidence of new particles.

Dijet Mass and Parametric Fit



Dijet Mass Residuals: (Data – Fit) / Fit

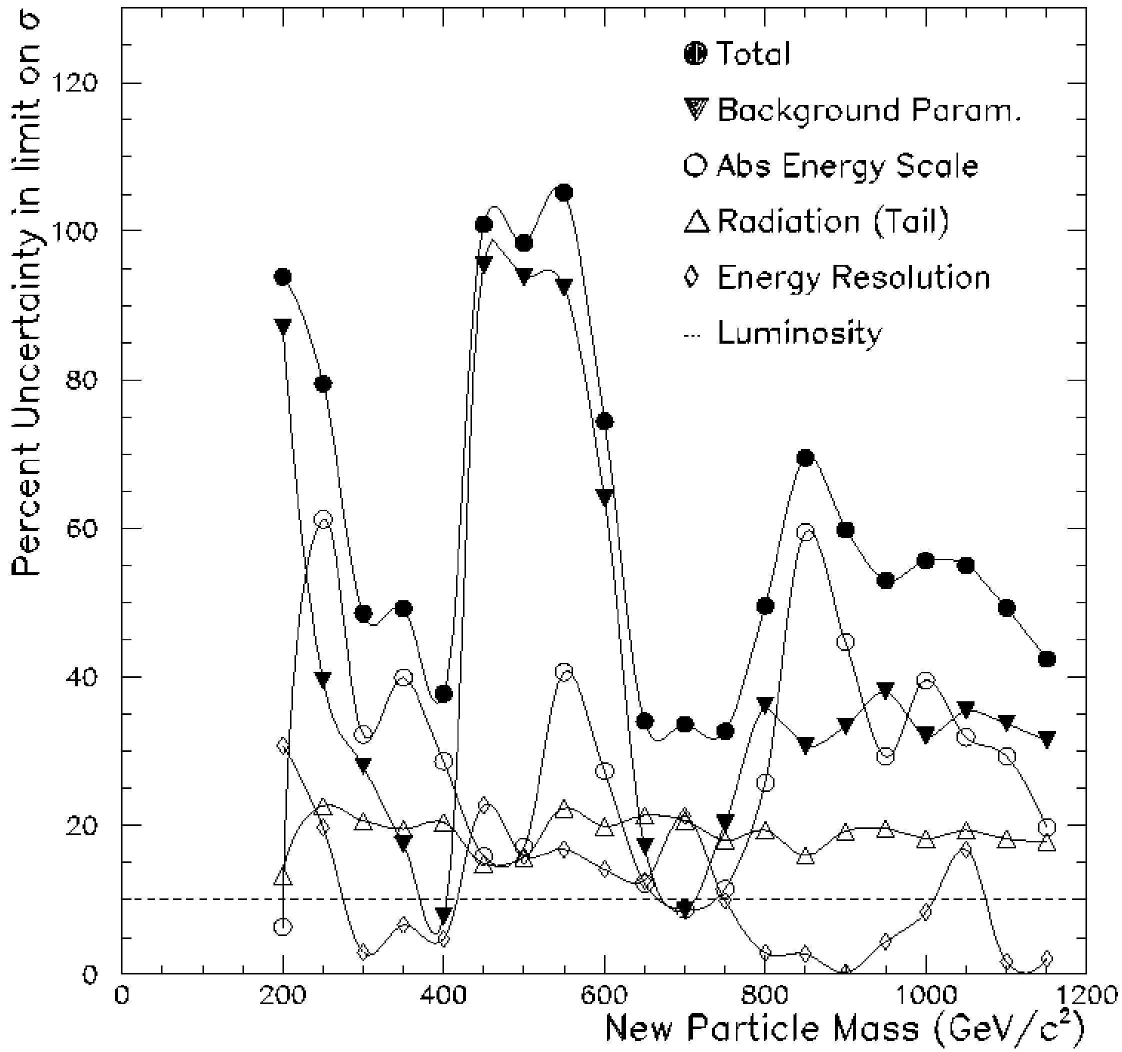


New Particle Limits

- Set upper limits on cross section for new particles.
  - Fit data to background parameterization plus a narrow resonance.
    - Use run 1 simulation of narrow resonances for now.
    - Dijet mass resolution (rms ~ 10%) dominates line shape.
    - There is a long tail to lower masses caused by QCD radiation.
  - Calculate likelihood vs. resonances cross section.
    - Statistical binned likelihood distributions and 95% CL limit points.
    - Recalculate limit for each systematic uncertainty shift.
    - Add resulting systematic shifts in quadrature to get total Gaussian sys.
    - Convolute statistical likelihoods with Gaussian systematic uncertainty.
  - Find 95% CL upper bound on new particle cross section.
    - Both with and w/o systematics.
  - Compare cross section upper limits to new particle theory.
    - As in run 1, we use lowest order predictions, but at $\sqrt{s}$ = 1.96 TeV.
    - We have predictions for Axigluons, colorons, q*, and E_6 diquarks.
    - Read off mass limits from the comparison.

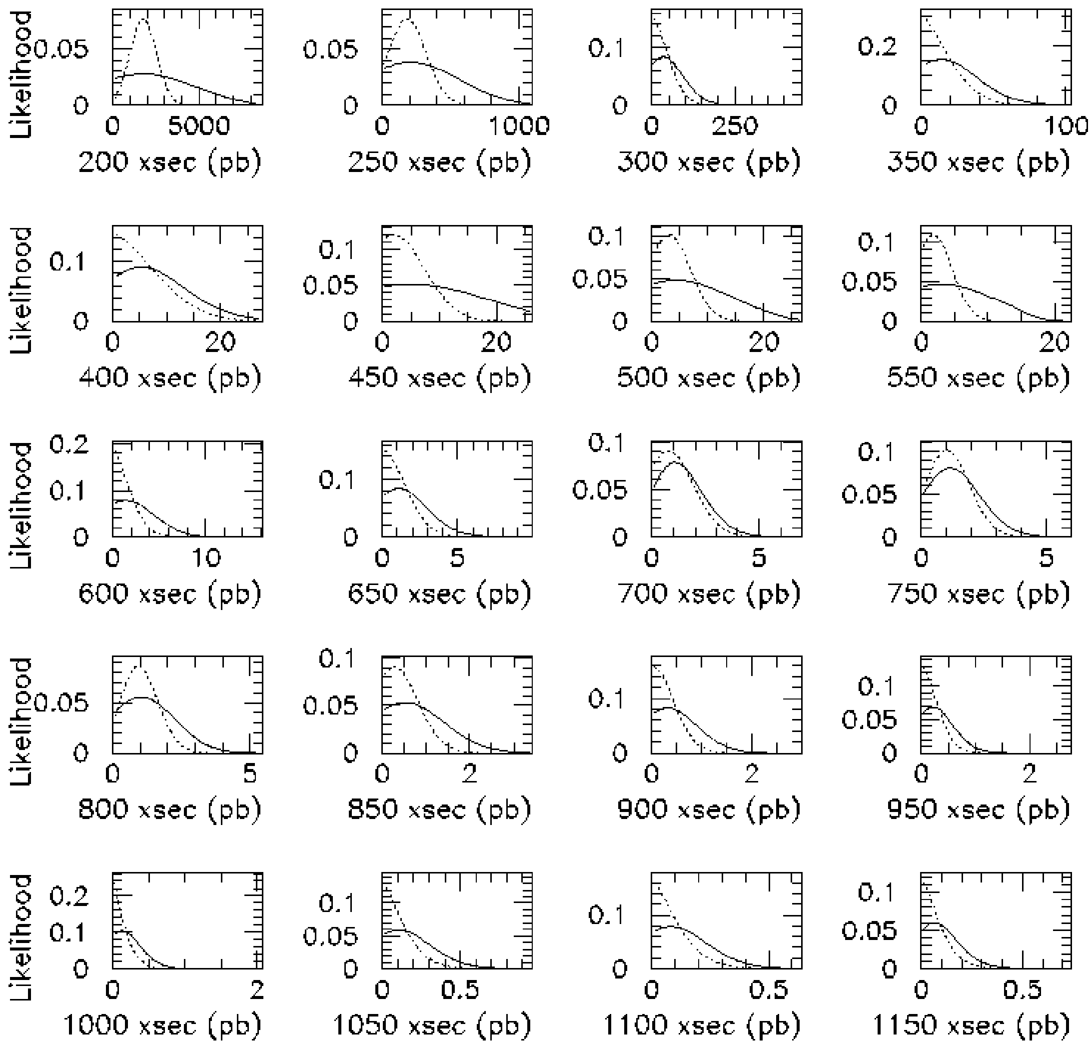
Systematics in Limit on Cross Section

- Systematics
  - Background Param.
    - Change from 4 to 3 parameter fit.
    - Allows for more signal because it fits the data worse.
  - Absolute E-Scale
    - 5% systematic.
  - Radiation
    - Cut out half of tail to low mass.
  - Energy Resolution
    - 10% systematic
  - Luminosity.
    - 10% at this stage.



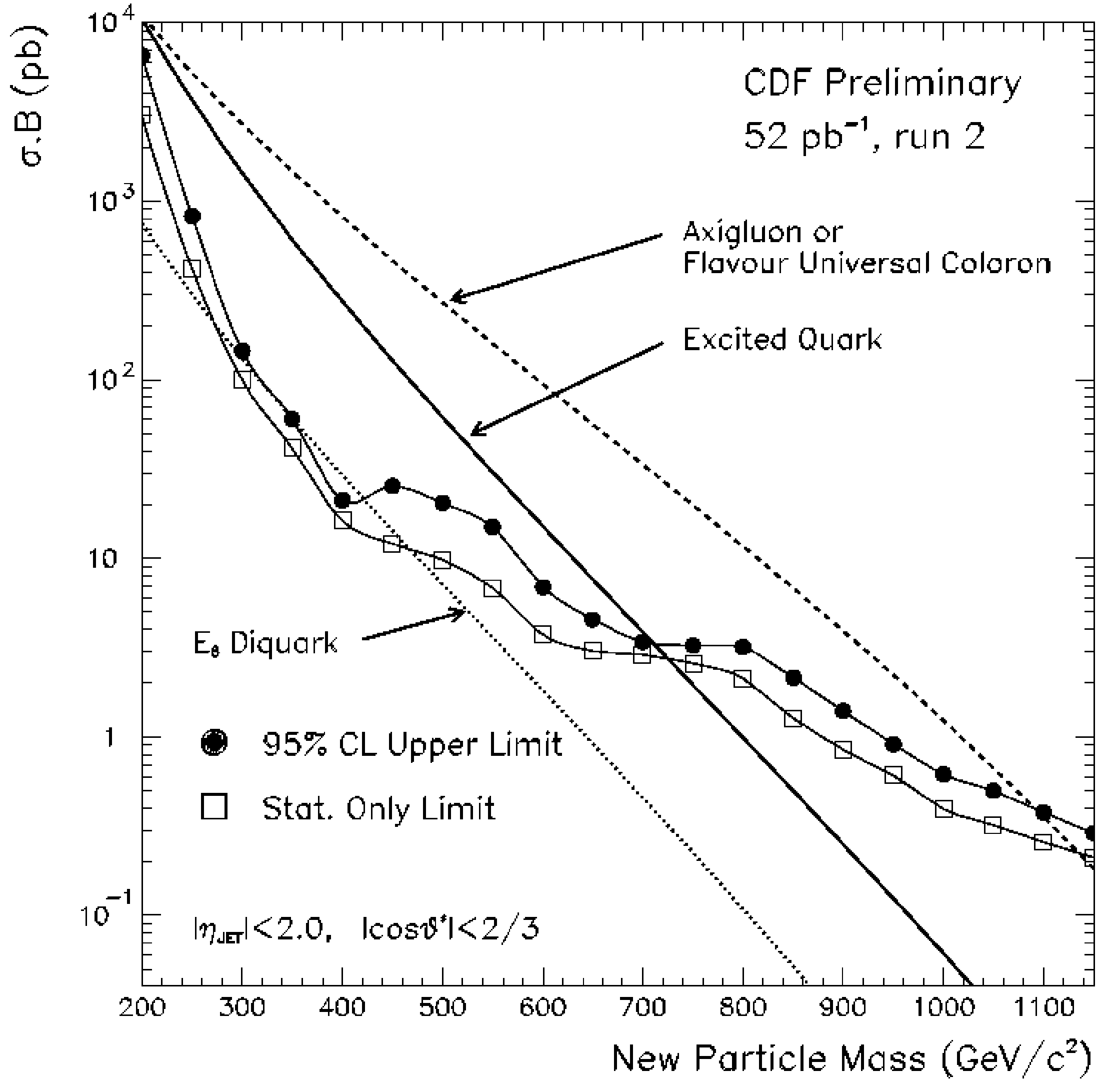
Likelihood Distributions

- Likelihood w/o systematics (dotted) and with systematics (solid) calclulated every 50 GeV for narrow resonances from 200 to 1150 GeV.
- Poisson like statistical likelihoods get smeared out by large Gaussian systematic.
- Integrate likelihood up to 95% area point to find 95% CL upper limit.



Limits on New Particles

- Very preliminary excluded masses of new particles at 95% CL in run 2
  - Axigluon or Coloron
    - M < 1.1 TeV
    - Run 1: M<980 GeV
  - Excited Quarks
    - M < 710 GeV
    - Run 1: M< 760 GeV.
  - E6 Diquark
    - 350<M<420 GeV.
    - Run 1: 290<M<420.



Conclusions

- We have a very preliminary dijet mass distribution in run 2.
  - The analysis was as close as possible to that in run 1.
  - The ratio of run 2 to run 1 cross section is as expected from QCD.
    - The energy scale corrections of the jet group look pretty good.
- We've done a very preliminary search for new particles decaying to dijets.
  - Mass distribution is smooth & well fit by background parameterization.
  - 95% CL upper limits determined on cross section and mass for new particles.
    - Axigluons or flavor universal colorons excluded for M<1.1 TeV at 95% CL.
    - Excited Quarks excluded for M<710 GeV at 95% CL.
    - E_6 Diquarks excluded for 350<M<420 GeV at 95% CL.
- First exclusion of a particle with mass > 1 TeV at the Tevatron!
  - Run 2 with 52 pb^{-1} is more sensitive to the highest mass physics than run 1.
- Next Steps
  - Rerun on larger sample, with recent processing, corrections, filters, . . .
    - If I cannot complete this in time for LaThuille, I believe this sample is blessable.
  - Add more systematic uncertainties as necessary.